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Dootrips: a CO_2-neutral global transportation system based on collaboration

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Abstract

With more than 30 million articles in 287 languages, Wikipedia allows volunteers from around the world make contributions towards the creation of the most complete encyclopedia ever written by humanity. By collecting 10-second contributions from over 100 million web users a day, project reCAPTCHA has digitized more than 13 million articles of The New York Times, dating from 1851 to the present. 12.5 million active users learn new languages every day using the collaborative platform Duolingo, and while doing so, they are helping to translate online content from one language to another in a costless manner. These are just some of the examples reflecting how we can harness the power of human collaboration to solve some of the most challenging problems in a sustainable manner. In this paper, we present the Dootrip system, a collaborative social-network based technology implementing a CO2-neutral global transportation system. By focusing on technology, information sharing, excess capacity and global collaboration, the Dootrip system effectively enables the transport of goods without incurring any economic cost and without altering the planet's ecological footprint. We have implemented the Dootrip system as part of the Labdoo humanitarian social network to help deliver unused laptops sanitized and loaded with education software to schools in need around the globe. Having planted the first seed in Southern California, in three years the Labdoo/Dootrip system has organically grown and spread across more than 90 countries, providing laptops to a growing number of more than 270 schools and servicing more than 65,000 children.

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1. Introduction

The history of technology development can be interpreted as "a struggle for efficiency". Under this view, every invention is understood as an artifact that has made human society more efficient in some specific way. Consider as an example technological developments in the area of human communication. More than 100,000 years ago when the first Homo sapiens started inhabiting the Earth, the cost of communication across oceans was infinite. With the invention of sailing (around 5000 BC), such cost became very high but bounded, and subsequent inventions—such as the telegraph (1837), the telephone (1875) and the Internet (1969)—have progressively reduced it further. This view tells us that as long as there continues to be inefficiencies (costs higher than zero), there will be a need for technology innovation. But in the limit, is it possible to create technology that brings costs down to zero?

To better understand the scope of this question, first we need to define the meaning of cost. Generally speaking, by cost we herein mean any side-effect produced from operating an artifact which, when isolated from all possible gains, makes our world worse off. This includes not only costs that can be easily monetized (e.g. the economic cost of the energy needed to run the artifact) but also less quantifiable costs such as the damage produced on our natural environment (e.g. any CO_2 emissions generated by the artifact).

In this paper we present the implementation of the Dootrip System, a zero-cost international transportation platform, and demonstrate that there exists a class of problems for which it is possible to develop technology with effectively zero economic and environmental costs.

The Dootrip System is fueled by two basic concepts: (1) the opportunity cost of an activity and (2) the technological capability that a given community has to efficiently manage information (the state-of-the-art). The first concept—the opportunity cost of an activity—is typically defined in the economic literature as the cost measured in terms of the value of the next best alternative forgone. For instance, if we decide to invest in the education of a child by purchasing a $500 computer, the opportunity cost of such activity comprises the set of all other activities that we could carry out with the $500—e.g., investing in ten mosquito nets priced at $50 or in one hundred $5 warm meals. The concepts of efficiency and opportunity cost are related through the following mechanism: an inefficient system is one that cannot fully utilize the true potential of its input resources, hence dissipating unused excess capacity as one of its outputs; such excess capacity, while a resource in itself, has an opportunity cost equal to zero because the system cannot make any use of it. Hence, inefficient systems are mechanisms which—by definition—generate resources with zero opportunity cost (ZOC). We leave in a world with plenty of inefficiencies. Every time we clean our teeth, most of water used is unnecessarily wasted; when driving to work solo, 80% of the total person-capacity in the car is unused; and so we could continue with a large list of daily activities that we do which generate ZOC resources.

The second concept relates to the capability that we as a community have to manage information and, specifically, to pin down the precise location and time where a given ZOC resource appears. We observe that a large number of resources have an opportunity cost equal to zero not because our technologies are not mature enough to enable their reutilization back into the production system but rather because we do not know with precision their location and time availability. Consider for instance the following example. A young man or woman located in a location λ would love to perform some volunteering work for a humanitarian cause, offering to carry out a certain task τ at time t; a NGO located near location λ is involved in a humanitarian mission requiring the implementation of a certain set of tasks which includes τ; if the NGO cannot pin down the location of the volunteer before time t, then such potential resource will remain unused. In our work, we will say that a resource is time-space constrained if the activation of such resource depends only on our capability to know with precision the time and location where such resource is available.

In this paper we argue that the current state-of-the art of our information systems provides us with such a tremendous capacity to pin down time-space constrained resources, that for the first time we are now capable of building large scale operational systems that can be propelled through the mobilization of ZOC resources—hence incurring no economic or environmental cost. This idea works similarly to the way other less information-intensive technologies operate. Consider as an example systems that are based on renewable energies such as the Sun. Solar energy has been a resource available to Earth since its very first days and yet for millions of years it has remained in large part a ZOC resource. With the invention of photovoltaic systems, we are now able to unlock a resource that otherwise would have stayed unused. Similarly, the world has plenty of time-space constrained resources that have been locked for thousands of years—such as the goodwill of a person to help a humanitarian cause, in our example above—only because we lacked the information systems capable of pinning down with precision their location and time.

We use the above concepts to design and implement the Dootrip System, a zero-cost (economically and environmentally) international transportation system. Applying our framework, the Dootrip System takes as ZOC resources those trips incurred by travelers and organizations around the world, offering them the possibility to volunteer a small courier task. The opportunity cost of these tasks is zero because these travelers need to undertake their trips regardless of the existence of the Dootrip System. The system uses a collaborative information management system—namely, a social network—to pin down the location and time availability of these trips, and assigns them to objects that need to be transported.

As we write this text, thousands of people are now in the air, on the ground and on the oceans, traveling to remote locations around the world. Some of them may have excess capacity in their luggage and, amongst these, some may be open to carry an object (perhaps a book, a bag of rice, or a laptop) to their destination to help some humanitarian cause. The only reason we cannot activate such type of ZOC resources is not due to a lack of goodwill, but rather to an immaturity of our information management systems. Yet as technology improves and as we continue to better organize the world's information, a new possibility opens to extend collaborative solutions to resolve some of the most challenging sustainability problems that we face.

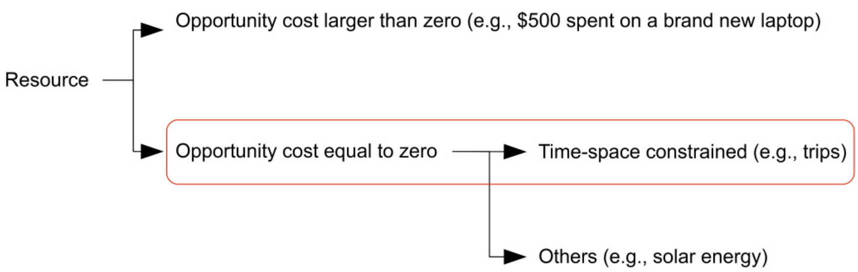

Fig. 1. Taxonomy of resources.
The Dootrip System leverages ZOC and time-space constrained resources to construct a CO2 neutral transportation system.

2. The Labdoo Project

The Labdoo.org project is a humanitarian social network (HSN) designed from the ground up as a collaborative system to help bring laptops to schools around the world [1]. Labdoo's mission statement focuses around the concept of providing used but well-conditioned laptops to schools so that children can gain free access to education. This mission is intimately related to a global problem commonly referred as the digital divide, a condition that arises because people having free access to information gain knowledge at a much higher pace than people who lack such access, creating an ever increasing gap between the two groups. While the idea of equipping children with computers to gain access to education is not a new one—there exist a good number of NGOs and organizations that focus around the same concept—a difference resides in the way Labdoo approaches its mission.

Labdoo uses a framework known as the wealth of networks [2] to help deliver its mission. In this approach, a large global mission is first divided into a very large number of small mini-tasks. Using technology, such mini-tasks are mapped to a large pool of volunteering resources distributed around the planet and executed in an asynchronous fashion. The same technology is then used to unite the results from all the mini-tasks in a coherent manner helping deliver the original global mission. It is worth noticing that this approach has been successfully used in other fields by other well-known projects such as the Wikipedia Project (focusing on the problem of writing an encyclopedia [3]), the reCAPTCHA Project (focusing on the problem of digitizing books [4]), or the Duolingo Project (focusing on the problem of translating content [4]). In our case, we apply this base framework to the problem of bringing a large quantity of laptops to schools around the globe in a way that economic and environmental costs are minimized or even eliminated.

A key to maximize the sustainability of the project is to make the mini-tasks as small as possible. This is because the smaller the tasks are, the bigger the global pool of potential resources, and the smaller the costs of executing each of these tasks. In the case of Labdoo, the four atomic and indivisible resources or mini-tasks required to bring a laptop to a school are:

(AT1) Unused laptop: an unused laptop has to be first donated.

(AT2) Sanitization: the laptop has to be sanitized and equipped with the education software (Labdoo loads every laptop with the free Edubuntu suite [5]).

(AT3) Storage/inventory: because supply, demand and shipment are not perfectly synchronized, storage is needed to keep the laptop while it waits for demand.

(AT4) Shipment: the laptop has to be shipped to a school.

In a traditional approach, the tasks above would be executed using a centralized workflow, preventing us from unlocking the true potential of the community. Instead, the wealth of networks principle [2] says that network and community gains can be maximized if we (1) identify first the smallest indivisible sub-tasks (in our case, AT1 through AT4) and (2) carry them out in a distributed manner, unlocking small resources wherever and whenever they are available. In the case of Labdoo, the technology used to logistically connect each of these mini-tasks towards delivering the larger mission is a social network. Because Labdoo is a grassroots non-profit platform and its objective is to serve a humanitarian cause, we refer to it as a humanitarian social network (HSN).

Amongst the four tasks, in this paper we focus on the description of the Dootrip System, the module used by Labdoo to logistically manage the shipment operations (AT4).

3. Problem Definition

The goal of the Dootrip System is to provide a collaborative international transportation platform that enables the shipping of goods (such as technology, food or medicines) to human development projects without incurring any additional economic or environmental costs. Although the platform was originally envisioned to support the transportation of laptops—as part of Labdoo's specific mission—the Dootrip System was designed as an open source, standalone and portable module applicable to the transportation of goods in general. For this reason, abstract objects will be considered in this paper instead of laptops. This approach allows other humanitarian projects (such as those dealing with the procurement of medicines, food, books, etc.) to potentially benefit from the Dootrip System.

As shown in Figure 2, the module consists of a user interface organized according to the different roles, a database that stores all events in the system (donations, requests, trips), an optimization module that computes optimal routes and a system administrator dashboard.

Before introducing the Dootrip framework, some initial concepts have to be formally defined:

- Dooject: the object donated by a user to the humanitarian social network;
- Dooquest: the request made by a project, consisting of a set of demanded doojects;
- Dootrip: the trip offered by a user to transport a given number of doojects. A dootrip is parametrized with the triplet [o, d, t], where o is an origin, d is a destination, and t is the time (including the date) of the trip;
- MegaDootrip: any set of one or more dootrips {d1, d2, …, dn } where the destination of di is equal to the origin of di+1; and
- Doostore: a location where doojects can be temporarily stored to help concatenate two dootrips. Although not limited to, a doostore can be a hub within the humanitarian network (e.g., an NGO or a company office, a university, a school, etc.) or the location of a single traveler.

The optimization problem that the Dootrip System aims at solving can be summarized as follows: given a set of doojects, dooquests, dootrips and doostores, identify the set of megaDootrips that allow for the transportation of a maximal number of doojects.

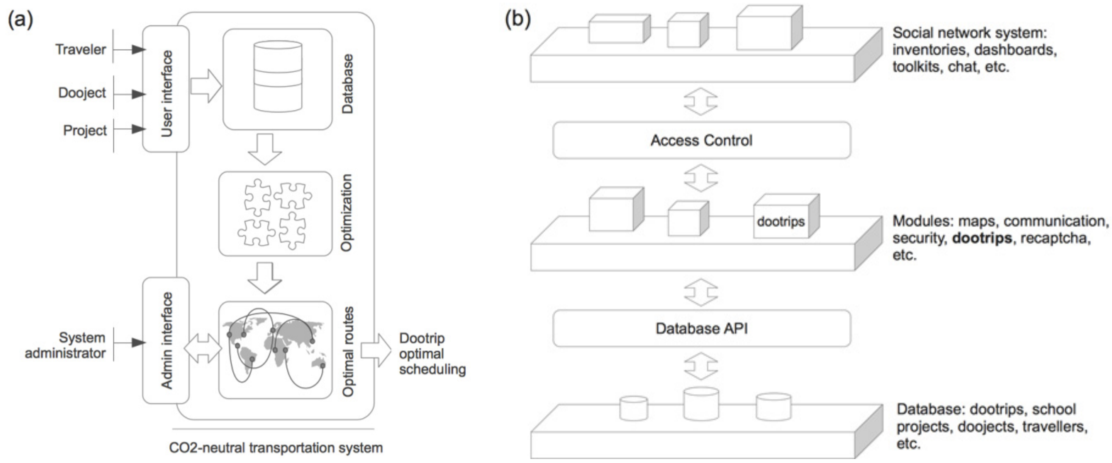

Fig. 2. (a) Workflow of a CO2-neutral transportation system based on collaboration;
(b) Layered architecture of the Drupal Content Management System used to implement the Labdoo social network.

4. Design and Implementation

The Dootrip System has been implemented as a portable standalone module using Drupal, an open source Content Management System (CMS) which provides a framework to construct collaborative, web-based knowledge systems following a modular architecture [6]. This approach enables the decoupling of the Dootrip module from the Labdoo project, and hence it allows any other organization's site based on the Drupal CMS to reuse the same module and enable its own CO2-neutral transportation system.

The Dootrip System consists of three main components (Figure 2a): (a) the dootrip users interface, used by the site's users to register their activities, (b) the optimization module, responsible for computing the optimal transportation routes, and (c) the administrator dashboard, used by the administrator to manage the different configuration options. The dootrip user interface provides a classic environment for users to register their events and its description is outside the scope of this paper. In the following sections, we focus on the description of the optimization module and the administrator control panel.

4.1. Algorithm

At its core, the Dootrip System automates the process of identifying routes that can be used to transport the maximal number of objects from one location to another. A natural approach to characterize this problem is to use a directed graph in which nodes indicate locations (e.g., doostores or destination projects) and edges indicate dootrips connecting two locations. Following this convention, donors, requesters and doostores add nodes to the graph, while travelers add edges. We will herein refer to this graph as the Dootrip graph.

Note that the Dootrip graph may contain unconnected nodes--i.e., users willing to donate doojects but without trips to transport the objects, schools requesting doojects but without trips to satisfy their demand, or doostores without any trips passing by. Likewise, as different travelers may register dootrips with the same origin or destination points, there can be more than one edge between the same pair of nodes and more than one incident edge on the same node.

Even though the problem description seems simple and unambiguous, several additional attributes have to be further considered:

- Every trip must have a maximum capacity, normally expressed as the maximum number of doojects that such trip can afford to transport.
- In order to concatenate different trips, the departure and arrival times for each trip have to be considered, as well as an additional safety time window to deal with eventual incidents (delays) or other connection-related issues. Users can register trips for many different activity plans (holidays, business, etc.), and the number of days a traveler stays in a destination may differ. This time window is important, as it can enhance the chances of connecting two dootrips. We will refer to it as the handover window.
- In some situations, two trips may not share a common source or destination, but the actual location may be close enough to effectively consider them as being connected. To increase the number of feasible solutions, the Dootrip System includes a notion of proximity or closeness. Two locations are considered close to each other if their distance is smaller than a certain configurable threshold (for instance, 50Km). In a Dootrip graph, locations that are close to each other are mapped onto the same node.

The matching of the arrival and departure dates of two or more dootrips based on their handover windows imposes a set of constraints to the optimization problem. Consider the following example. A laptop is donated in New York while a school in Nairobi requests one laptop to build a new computer lab. A user u1 contributes a dootrip d1 from New York to Barcelona and another user u2 contributes a second dootrip d2 from Barcelona to Nairobi. The megaDootrip {d1, d2} can be used to transport the donated laptop to its destination if and only if the following holds:

- d1's arrival time is before d2's departure time.
- There is a non empty intersection of days between the set of days u1 can deliver the dooject and the set of days u2 can receive it in Barcelona, or there's no intersection but there is a doostore in Barcelona which can store the dooject until u2 can collect it.

To reflect the above constraints, the edges of the Dootrip graph include the following attributes: (1) the capacity, (2) the departure and arrival time, and (3) the departure and arrival handover windows.

The nature of the problem leads to a classical max-flow algorithm with the addition of timing constraints and the capacity limits of edges between nodes. We have considered different max-flow algorithms and selected the Dinitz Algorithm [7], which we have modified to meet the particular constraints of our problem. While the literature in this field is rich and our problem can certainly accept other algorithmic approaches, two favorable properties of the Dinitz Algorithm within the context of this work are:

- Shortest path prioritization. The megaDootrips are formed by more than one dootrip, requiring at least the synchronization of two persons meeting in a specific place within a specific time frame. The more dootrips a megaDootrip has, the higher the chances of missing a connection along the path. This risk is similar to the risk faced by airplane travelers of missing a flight in a trip with multiple layovers. Compared to other more general solutions such as the Ford-Fulkerson Algorithm [8], the Dinitz Algorithm yields a solution which prioritizes shortest paths.
- Complexity. When considering the scalability of the system, we observe that the number of edges will tend to grow much faster than the number of nodes. This comes from the fact that the number of potential travelers is a few orders of magnitude larger than the number of potential destinations. (The world has more than 7 Billion people but there are only about 200 capital cities.) Therefore, algorithms with a complexity less sensitive to the number of edges will tend to scale better. From this perspective, we note that the complexity of the Dinitz Algorithm is linear with respect to the number of edges, unlike other solutions such as the Edmonds-Karp which present a quadratic cost.

Due to space limitations, we omit a detailed description of the algorithm implementation and refer the reader to our extended Technical Report [9].

4.2. Integration with the Labdoo Social Network

The Dootrip System has been developed as a generic standalone Drupal module and it has been tested by integrating it into the Labdoo's social network [6]. This section summarizes the main steps required to integrate the Dootrip module into a target Drupal site.

The Dootrip module is packaged following the standard Drupal module procedure and, therefore, it can be installed in any Drupal-based site. Since the Dootrip module leverages other standard modules, prior to its installation, the following Drupal modules must be enabled:

- Location module: Needed to store the location of the different resources.
- Gmap module: Used to display the location of all the resources.
- Date module: Provides useful tools to manage date-related information.
- Trigger module: Provides a framework to create triggers that are executed automatically upon certain events.

Once the above dependencies are resolved, the Dootrip module can be installed and configured. To preserve its generality, the Dootrip module makes no assumption on how the various objects of the system are defined. Instead, administrators configure during installation the names of the tables in the database corresponding to each of these objects (e.g., doojects, dootrips, dooquests, etc.) and the names of the fields in these objects that define their attributes (e.g., the arrival time of a dootrip, the demand of a destination project, etc.).

After configuring the different objects and parameters, the module becomes functional. One can easily test it by visiting the new sections of the site's menu. One of these sections, the Dootrip Panel, displays on a map the location of the doojects, dootrips, destination projects and doostores and implements a filter to control the objects displayed on the map. This view is illustrated in the Figure 3.

Fig. 3. Inventory of doojects integrated as part of the Labdoo social network.

5. Study Cases

In Ndoni, Nigeria, the Saint Agnes School took the mission of creating a computer lab with 50 laptops for their 500 students. In one dootrip story, four unused laptops of four individuals in California were localized. Through the dootrip social network, users willing to donate excess luggage capacity to transport the laptops from California to Nigeria were also localized. A Labdoo volunteer was traveling from California to Barcelona stopping by New York for a few days. He carried the four laptops from California to New York. The laptops were then picked up by a representative from an NGO who frequently travels between New York and Ndoni. The NGO representative took the laptops to Ndoni in his following trip using available space in his luggage. Similarly, six other laptops were carried using dootrips that connected Barcelona and California with New York and Ndoni. A few weeks later, eleven more laptops were also localized and carried from Hinschu, Taiwan, to San Jose, California, and from there exercising one more time the megaDootrip from California to Ndoni via New York to reach their final destination.

In Rome, workers in the headquarters of the Food and Agriculture Organization (FAO) created their own Labdoo hub to help coordinate their own dootrips to bring laptops to schools in need. (It is important to notice that these are personal projects run by FAO employees independently from FAO and that Labdoo has no formal collaboration or affiliation with FAO.) As part of an organization which operates in 193 countries, the Labdoo team in Rome has access to a large network of people who constantly travel to distant locations, often doing so with excess capacity in their luggage. As a result, in a bit more than one year, the Labdoo hub in Rome created 14 computer labs spread in ten different countries: Argentina, Bolivia, Bosnia, Brazil, Cambodia, Colombia, Ecuador, Italy, Laos and Thailand. They also uncovered a CO2-neutral route between Barcelona and Rome using a ground transportation company which donates excess capacity in their trucks (next to food cans and various other commercial packages) to bring the laptops. A Labdoo hub in Barcelona serves as the origin of another megaDootrip, providing laptops to Rome and from there to their final destinations. As an anecdote, the hub in Rome has so many dootrips available that they call the laptops they receive from Barcelona "panecillos calientes", Spanish for "hot bread", to illustrate the speed in which they are able to assign laptops to travelers leaving from Rome.

In a bit more than a year, Labdoo hubs in Germany uncovered CO2-neutral routes to more than 50 schools distributed across Africa, Europe, South America and Asia. Similar successful stories took place during the same time frame originating from Labdoo hubs created in the countries of Italy, Mexico, Spain, Switzerland, Taiwan and the United States. At the time of this writing, the Labdoo humanitarian social network is delivering laptops using the Dootrip System to more than 270 schools in a growing network that includes more than 90 countries. A subset of this network is illustrated in Figure 5.

Fig. 4. Some of the Dootrip stories occurring inside the Labdoo aid network.

Fig. 5. Some of the CO2-neutral routes that the Dootrip System has unlocked to help bring laptops to more than 270 schools spreading over more than 90 countries.

6. Conclusion

The Dootrip System is a CO2-neutral international transportation platform that takes advantage of those trips incurred by travelers and organizations around the world to provide zero opportunity cost (ZOC) courier tasks. Constructed as a humanitarian social network, the platform leverages a collaborative information management system where three different user types share their offers and requests: donors are users who donate unused objects (for instance, laptops), requesters are users from organizations who request the donated objects to help support their development activities, and travelers are users who voluntarily offer their trips to transport the objects freely. The system collects location, time and capacity information from the trips, computes the maximal amount of goods that can be transported to satisfy the demands of the requested humanitarian projects, and coordinates the users involved in each phase of the shipping process.

With this proposal, we demonstrate that there exists a class of problems for which it is possible to develop technology with effectively zero economic and environmental costs, and provide a valuable tool that enables the transfer of excess resources from more developed to less developed regions. Leveraging the goodwill and desire of cooperation of thousands of “dootrippers” around the globe, and by discovering, unlocking and activating ZOC transportation resources using a social network based system, many humanitarian organizations have received the equipment necessary to develop their activities and, consequently, the lifecycle of unused resources has also been extended. At the time of this writing, the Labdoo.org Social Network project and its Dootrip System are being utilized in more than 90 countries to collaboratively deliver laptops to more than 270 schools in five different continents without incurring any economic or environmental cost.

The struggle for efficiency and sustainability must continue. Although Labdoo.org focuses on supplying used laptops to schools around the globe, the Dootrip System has been designed as an open source, standalone and portable module applicable to the transport of any type of goods. Future efforts will focus on tuning and improving the system services, and we will explore ways in which the Dootrip System can be integrated into the logistical workflow of other organizations that could potentially benefit from a CO2-neutral global transport system.

Acknowledgements

This work would not have been possible without the goodwill effort of all the labdooers around the world who carry out the Labdoo mini-missions, whether from home, from work, from school or anywhere, to help bring laptops loaded with education software to schools in a globally coordinated manner. To find out more about each of these small but meaningfully connected stories, go to www.labdoo.org. We also want to thank Daniel Massaguer for his participation in this implementation. This project has been developed with the support of the Center of Cooperation for Development at the UPC Barcelona Tech. Adrian also wants to thank I2CAT Foundation for awarding him a scholarship to develop this work as part of his bachelor's final thesis.

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